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Effects of a Lignosulfonate-Type Drilling Mud on Development of Experimental Estuarine Macrobenthic Communities

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16. ABSTRACT

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EFFECTS OF A LIGNOSULFONATE-TYPE DRILLING MUD ON DEVELOPMENT OF EXPERIMENTAL ESTUARINE MACROBENTHIC COMMUNITIES[1]

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ABSTRACT: Drilling mud, as used in exploratory drilling for oil offshore, affected the composition of estuarine communities that developed from planktonic larvae in aquaria containing sand and flowing estuarine water. Aquaria contained: sand only; a mixture (by volume) of 1 part mud and 10 parts sand; 1 part mud and 5 parts sand; or sand covered by 0.2 cm mud. For all environments, annelids, mollusks, arthropods, and coelenterates were the numerically dominant phyla collected in a 1 mm mesh sieve after eift weeks exposure; a total of 1,025 animals, representing 45 species, was collected. Annelids and coelenterates were significantly fewer (α =0.05) in aquaria containing drilling mud than in the control aquaria. Arthropods were significantly affected only by mud cover over sand; mollusks also were diminished in this environment, but not significantly. Exposure to concentrations of drilling mud reduced not only the number of individuals, but also the frequency of occurrence of macrobenthic species. Thus, the average number of annelid species in 1 part mud: 5 parts sand aquaria or in mud-covered aquaria was significantly less than in control aquaria. The average number of arthropod species per aquarium was also significantly less in the mud-cover exposure than in the control. Discharge of large quantities of drilling mud at levels tested in the laboratory could adversely affect the colonization of various substrata by benthic animals in nature.

Drilling muds are used in exploratory drilling offshore primarily to bring up drill cuttings, maintain hydrostatic pressure, prevent corrosion of pipe, and cool and lubricate the bit. They generally consist of aqueous clay suspensions containing barium sulfate and a variety of additives. However, constituents and their amounts vary with drilling conditions, such as type of formation and depth of drilling. Drilling muds are chemically complex and may include pH-control substances, bactericides, sealants, corrosion inhibitors, emulsifiers, flocculants, lubricants, foaming agents, filtrate reducers, and weighting agents (Robichaux, 1975; Simpson, 1975). Although most of the drilling mud is recovered and recycled, tons of mud and cuttings are discharged as turbidity plumes and deposited on the bottom near drilling sites (Shinn, 1974; George, 1975). Some mud is continually lost with the cuttings, and discharges of old or excess mud may occur when a different type is needed or at the conclusion of drilling.

The impact of drilling rig discharges on the estuarine and marine environment is unknown because relatively few toxicological studies have been conducted in salt-water environments. Acute bioassays of drilling muds or some of their components have shown little or no toxicity in fresh or salt water to various algae, oysters, fish, and crustaceans

[1] Gulf Breeze Contribution No. 370.

(Daugherty, 1951; Anderson, 1953; Cabrera, 1971; Falk and Lawrence, 1973; Grantham and Sloan, 1975; Bureau of Land Management, 1978). However, in long-term tests, constituents such as pentachlorophenol (bactericide) and barite (weighting agent) adversely affected the composition of meiofaunal and macrofaunal benthic communities colonizing sand during nine or more weeks (Tagatz *et al.*, 1977, 1978; Tagatz and Tobia, 1978; Cantelmo and Rao, 1978; Cantelmo *et al.*, submitted for publication).

Our study was initiated to determine the effect of whole drilling mud on development of estuarine communities which result from settling planktonic larvae. We investigated the impact of a mud cover over the substratum, as well as a mixture of mud and clean sediment.

METHODS AND MATERIALS

The effect of whole drilling mud on colonization was determined by comparing numbers and species of animals that grew from planktonic larvae in treated aquaria for eight weeks (August 15 to October 10, 1977) with animals that grew in untreated aquaria. Larvae entered the aquaria from the natural component of plankton in flowing unfiltered seawater. We used four apparatuses, described by Hansen (1974), each consisting of 10 adjacent aquaria, 56 cm long, 9 cm wide, and 12 cm high. Aquaria were filled to a depth of 6 cm with either clean sand or sand and drilling mud. Only the eight inner adjacent aquaria of each 10-aquaria apparatus were used in the experimental design; the outermost aquaria contained sand and eliminated any "end of the row" difference. Water levels were maintained at 9 cm (3 cm above substratum).

Drilling mud was obtained from the settling pit of an active drilling rig in the Gulf of Mexico off the coast of Louisiana; sand was dredged a year previously from Santa Rosa Sound, Florida. Our mud sample was a lignosulfonate-mud type, a water-base clay containing barium sulfate to control density and ferrochrome lignosulfonate to control flow and filtration properties. We do not know the identity of other components that may have been added for other specific functions. The mud was prepared as a heavy type, 17.6 lbs. per gallon (8 kg per 3.8l) for use at a depth of 13,370 feet (4,075m). Solid content was 34% by volume and 72% by weight; water content, 66% by volume and 28% by weight; pH 12.5. (Mud was refrigerated until used in the experiment.) The silica sand for our study consisted of a mixture of 25% coarse particles and 75% medium particles; particle size ranged from 200 to 800 microns.

The sequence of control and treated aquaria among apparatuses was determined by a randomly selected 4 x 4 Latin square pattern to eliminate bias due to position. Eight aquaria contained only sand (control), 8 contained a mixture of 1 part mud and 10 parts sand (1:10) by volume, 8 contained 1 part mud and 5 parts sand (1:5), and 8 contained 5.8 cm of sand covered with 0.2 cm of mud (cover). (The 0.2-cm cover was formed by the solid materials in drilling mud that settled on aquaria sand previously saturated with seawater; the liquid portion of the mud was allowed to flow from the aquaria.)

Seawater with its constituent plankton was pumped from Santa Rosa Sound to an overflow box where four adjacent siphons supplied water at a rate of 2.5l /min to four constant-head boxes on top of the apparatuses. Flow to each aquar-

ium was maintained at 200 ml/min by adjusting the height of a 3.2-mm diameter hole in each of 10 standpipes in the constant-head box. Water flowed from the aquaria through notched end openings into a common drain. Large predator animals (such as crabs wider than 10 mm) escaped through these openings before their number could drastically affect community structure. Salinity of the water averaged 27.5‰ (24.0 to 32.0‰); temperature, 28.0°C (22.5 to 31.0°C).

After eight weeks, animals were collected by siphoning contents of the aquaria into a 1 mm mesh sieve, preserved, and identified. Analysis of variance and Duncan's multiple range test were used to compare numbers and species of animals in control and treated aquaria. Results are presented as pooled data from each drilling-mud concentration and the control. Tubes of the serpulid worm, *Pomatoceros* sp., partially encrusted the walls of all aquaria. This species is not included in the data because accurate counts could not be obtained (many small worms fragmented when scraped from aquaria walls).

RESULTS

The harvest at eight weeks yielded 1,025 animals, representing 45 species of 8 phyla (Table 1). The five most abundant species were the polychaetes, *Armandia maculata* (223) and *Mediomastus californiensis* (88); the gastropod, *Acteocina canaliculata* (75); the amphipod, *Corophium acherusicum* (74) and the anemone, *Aiptasia pallida* (98). The numerically dominant phyla were Annelida, Mollusca, Arthropoda, and Coelenterata.

Abundance of animals was affected by drilling mud (Fig. 1). Total numbers of animals and average number of species per aquarium were significantly less ($\alpha = 0.05$) in aquaria containing sand under the mud cover than in unexposed aquaria (Table 2). Numbers of animals in aquaria containing mixtures of mud and sand also differed ($\alpha = 0.05$) from the numbers in control aquaria; numbers of species did not significantly differ.

The average number and range of animals per aquarium are shown by phylum in Table 3. Although inter-aquaria variability was great, pooling the data of eight replicate aquaria for each treatment readily indicated the effect of drilling mud in this experiment.

Annelida and Coelenterata were most affected by drilling mud. Significantly fewer ($\alpha = 0.05$) annelids and coelenterates (*Aiptasia pallida*) were observed in aquaria under treatment than in control aquaria. Number of species of annelids per aquarium also was significantly reduced in 1 mud: 5 sand mixture and in mud-covered aquaria.

Arthropods, particularly the amphipod, *Corophium acherusicum*, were significantly affected only by mud cover; mollusks also were reduced but not significantly, in aquaria with mud cover. Relatively few Platyhelminthes, Nemertea, Echinodermata, and Chordata were collected.

Community structure changed as a result of contamination by drilling mud. Although annelids were dominant in number in control and in all concentrations, relative abundance of other phyla varied. For example, coelenterates were second in abundance in the control, but fourth in abundance in all concentrations.

DISCUSSION AND CONCLUSIONS

Effects of whole drilling mud on development of estuarine communities were similar to those found for barite

Table 1. Animals collected from control aquaria and from aquaria exposed to drilling mud for eight weeks.

Animal	Control	Mud: Sand 1:10	Mud: Sand 1:5	Mud Cover	Total animals
ANNELIDA					
Armandia maculata	126	55	39	3	223
Mediomastus californiensis	41	21	7	19	88
Polydora socialis	27	24	3	13	67
Trochochaeta multisetosa	27	19	8	3	57
Neanthes succinea	4	16	16	15	51
Nereis pelagica occidentalis	17	4	7	7	35
Podarke, near *guanica*	10	3	10	1	24
Polydora websteri	4	8	2	6	20
Prionospio heterobranchia texana	3	8	4	2	17
Capitomastus aciculatus	0	6	5	1	12
Lumbrineris alata	10	2	0	0	12
Capitata capitata	0	4	1	6	11
Polydora ligni	2	1	1	1	5
Dasybranchus lunulatus	4	0	0	0	4
Prionospio cirrifera	0	1	1	0	2
Chone duneri	0	0	1	0	1
Loimia viridus	0	0	1	0	1
Megalomma bioculatum	0	1	0	0	1
Sabella microphthalma	1	0	0	0	1
Terebella rubra	0	1	0	0	1
MOLLUSCA					
Acteocina canaliculata	23	16	19	17	75
Laevicardium mortoni	16	7	5	4	32
Crassostrea virginica	2	2	3	3	10
Musculus lateralis	4	2	4	0	10
Mitrella lunata	1	1	5	1	8
Tellina alternata	1	5	0	1	7
Diastoma varium	2	3	1	0	6
Crepidula plana	3	1	1	0	5
Abra aequalis	0	1	2	1	4
Raeta plicatella	0	1	0	0	1
Tagelus divisus	0	0	1	0	1
Triphora nigrocincta	1	0	0	0	1
ARTHROPODA					
Corophium acherusicum	26	14	29	5	74
Rhithropanopeus harrissii	2	7	8	4	21
Eurypanopeus depressus	7	3	3	2	15
Upogebia affinis	1	1	2	0	4
Balanus improvisus	0	1	1	0	2
Macrobrachium sp.	0	1	0	0	1
Panopeus herbstii	0	1	0	0	1
Pinnixa retinens	0	0	1	0	1
COELENTERATA					
Aiptasia pallida	58	13	23	4	98
ECHINODERMATA					
Leptosynapta inhaerens	6	1	1	0	8
NEMERTEA					
Nemertea	0	0	3	0	3
CHORDATA					
Molgula manhattensis	0	1	1	0	2
PLATYHELMINTHES					
Polycladida	0	2	0	0	2

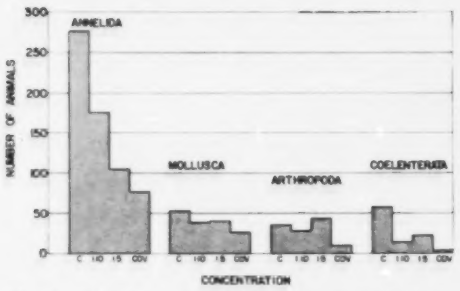

Fig. 1. Number of animals, by selected phyla, collected from control aquaria (c) and aquaria treated with drilling mud (1 mud: 10 sand; 1 mud: 5 sand; 2-mm cover) for eight weeks.

($BaSO_4$), the primary constituent and usual weighting agent used in muds (Tagatz and Tobia, 1978). Annelids were most affected by whole drilling mud and by barite. In both instances, numbers were significantly reduced in a mixture of 1 part toxicant to 10 parts sand. *Armandia* sp., the most abundant annelid in both studies, was particularly sensitive to all concentrations.

Also, a 2 mm cover of mud or a 5 mm cover of barite had greater effects on colonization than did mixtures of toxicant and sand. Annelids primarily occurred near the surface and, therefore, were exposed to a higher concentration of toxicant as a cover than as a mixture. Woodin (1974) found a preference of polychaetes (five families) for the upper 2 cm of a natural mud flat.

Mixtures of toxicant and sand appeared to have little effect on mollusks, but a cover of whole mud or barite caused reductions in abundance. *Laevicardium mortoni* was adversely affected by both compounds. Another mollusk common to both studies, *Acteocina canaliculata,* was susceptible to all concentrations of barite, but not to whole drilling mud.

A cover of whole mud or barite decreased abundance of the arthropod, *Corophium acherusicum;* crabs did not appear to be affected by either compound. Numbers of the coelenterate, *Aiptasia pallida,* were reduced by all concentrations of mud; *Edwardsia* sp., by all concentrations of barite.

Discharge of large amounts of drilling mud, at levels tested in the laboratory, could adversely affect the colonization of various substrata by macrobenthic animals in nature. Changes in species

Table 2. Animals (total number) and species (average number per aquarium), by phylum, collected from control aquaria and aquaria exposed to drilling mud for eight weeks.

	Control		Mud 1:10		Mud 1:5		Mud Cover	
Phylum	No.	Sp.	No.	Sp.	No.	Sp.	No.	Sp.
Annelida	276	7.8	174*	7.9	106*	5.8*	77*	5.1*
Mollusca	53	3.0	39	3.0	41	2.9	27	1.8
Arthropoda	36	1.8	28	2.1	44	1.9	11*	0.8*
Coelenterata	58	0.8	13*	0.2	23*	0.2	4*	0.4
Echinodermata	6	0.2	1	0.1	1	0.1	0	0
Nemertea	0	0	0	0	3	0.1	0	0
Chordata	0	0	1	0.1	1	0.1	0	0
Platyhelminthes	0	0	2	0.2	0	0	0	0
All phyla	429	13.5	258*	13.8	219*	11.1	119*	8.0*

*Significantly less than control at 5% level; significance is indicated only for the four most abundant phyla.

Table 3. Average number and range of animals per aquarium (by phylum) collected from control aquaria and aquaria exposed to drilling mud for eight weeks.

Phylum	Control	Mud 1:10	Mud 1:5	Mud Cover
Annelida	34.5 (21-51)	21.8 (14-32)	13.2 (3-34)	9.6 (6-16)
Mollusca	6.6 (1-13)	4.9 (0- 9)	5.1 (0-19)	3.4 (0- 6)
Arthropoda	4.5 (1- 8)	3.5 (1- 6)	5.5 (1-19)	1.4 (0- 5)
Coelenterata	7.2 (0-29)	1.6 (0- 7)	2.9 (0-15)	0.5 (0- 2)
Other phyla	0.8 (0- 3)	0.5 (0- 2)	0.6 (0- 3)	0 (0-)
Total	53.6 (34-69)	32.3 (22-41)	27.3 (7-46)	14.9 (9-24)

composition and relative abundance of settling organisms could alter interactions among resident animals and interrupt community stability. These changes could be due to toxic constituents of drilling muds, such as the bactericide, pentachlorophenol (Tagatz *et al.*, 1977; 1978), or to non-toxic components such as the clay weighting agent, barite (Tagatz and Tobia, 1978).

The relation of sediment type to the character of settling benthos is well documented. Bloom *et al.* (1972) found that grain size of sediment was important in determining if intertidal infauna were dominated by filter feeders or by deposit feeders in Tampa Bay, Florida. Pequegnat (1975) reported a striking parallel between the amount of fine sediments and the types and abundance of meiofauna in the U. S. Virgin Islands. Johnson (1970) discussed successional changes within benthic communities due to disturbances involving a change in the texture of the substrate. According to George (1975), benthic mud-eating or detritophagous animals probably are more susceptible to the impact of drilling mud than are carnivorous animals and their loss can bring about changes in species diversity and community organization. In addition, settling pelagic larvae discriminate between favorable and unfavorable substrata (Thorson, 1966). The type of animals that settle and grow in a particular locality appears to be based upon the physical composition and organic content of the sediment (Thorson, 1957). Thus, large quantities of drilling mud mixed with or covering marine sediments would change sediment granulometry and could influence the distribution and abundance of settling organisms.

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